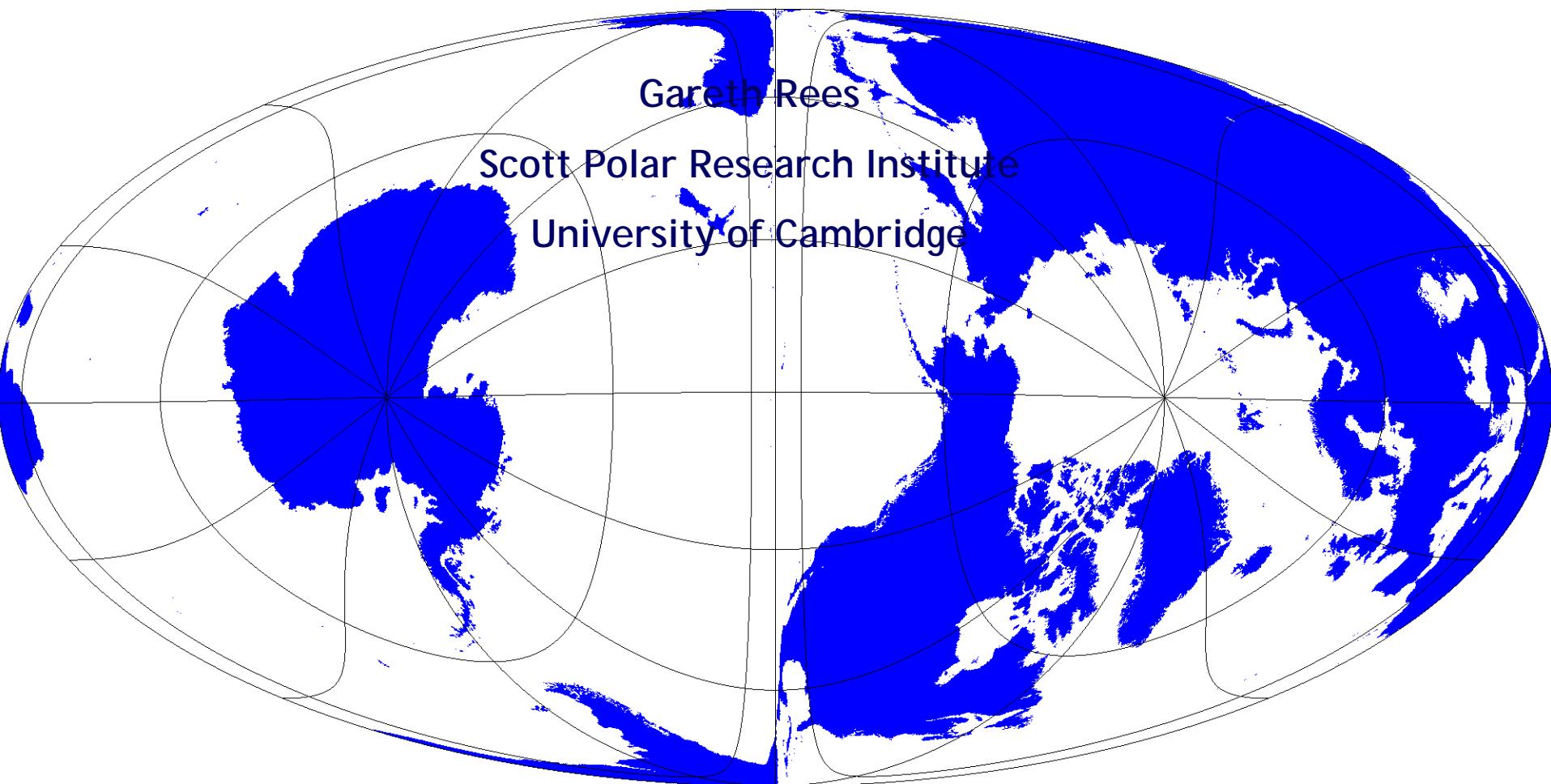


Characterisation of Arctic treelines by LiDAR and multispectral imagery

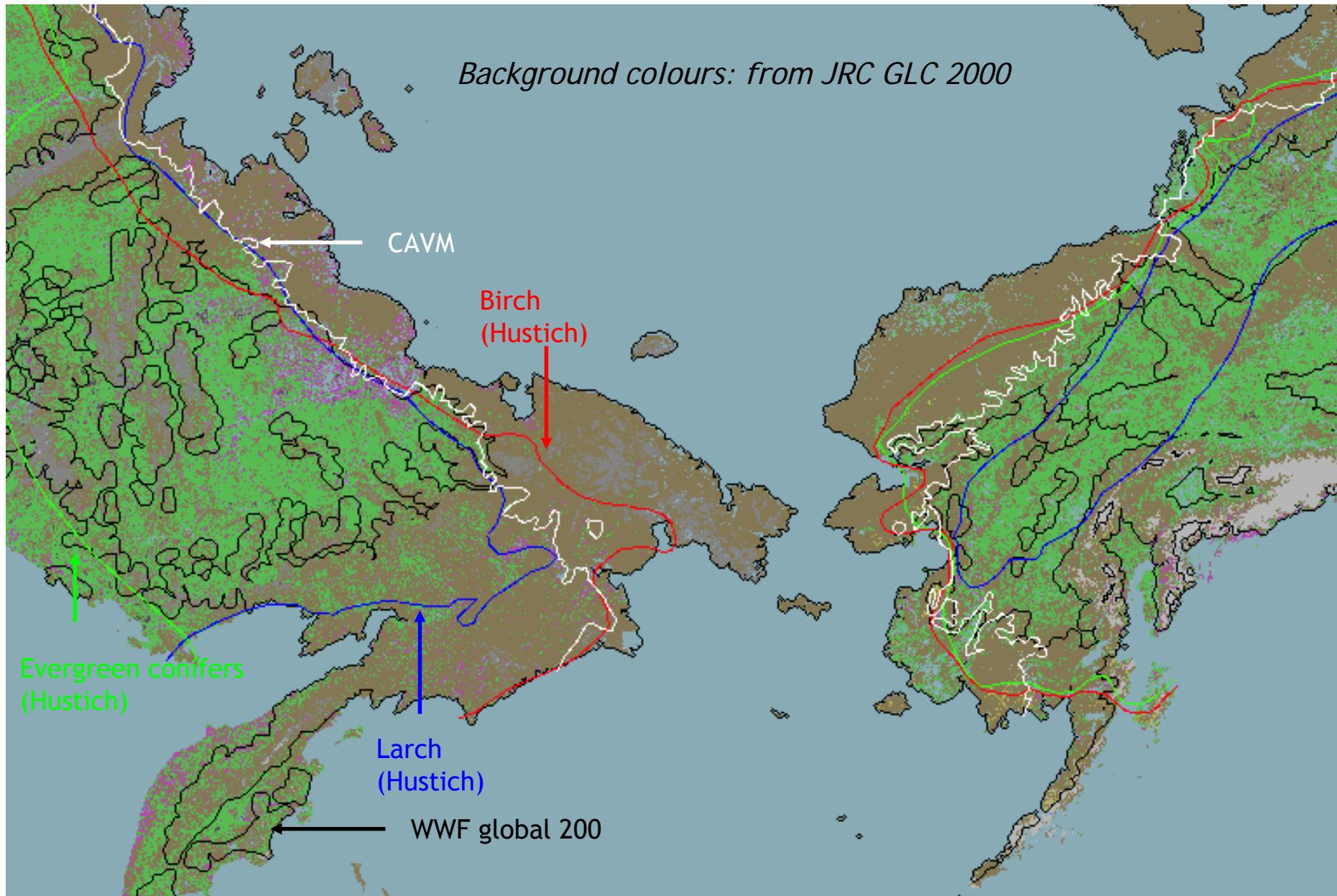


The tundra-taiga ecotone ('arctic treeline') is

- huge
- important
- not very well understood (or well defined, or in an agreed location)
- target of a large IPY core project consortium



(At least) six different treelines...



PPS Arctic, IPY core project #151

Present day processes, Past changes, and Spatiotemporal variability of biotic, abiotic and socio-environmental conditions and resource components along and across the Arctic delimitation zone

Coordinators:

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Coordinator of PPS Arctic Canada:

Karen Harper (karen.harper@bio.ulaval.ca)



Contributors to PPS Arctic

13 countries

37 institutions...

...and counting -

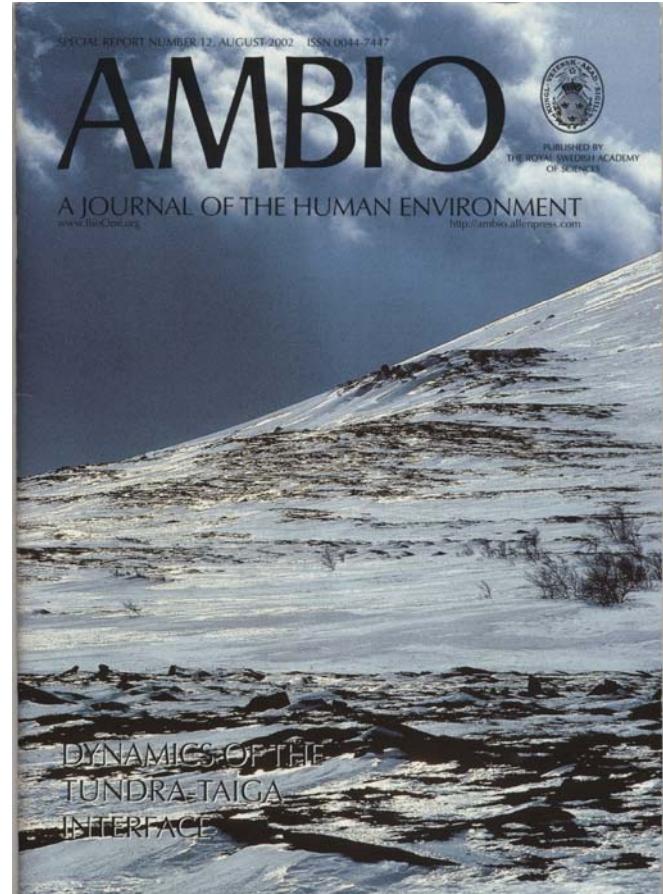
not closed!

Argentina	Inanglia-Cricyt-Conicet	Trombotto, Dario
Australia	Monash U.	Beringer, Jason
Austria	IIASA	Nilsson, Sten
Canada	Alberta U.	Danby, Ryan
Canada	Alberta U.	Kershaw, Peter
Canada	Carleton U.	Doubleday, Nancy
Canada	Lakehead U.	McIntyre, Norman
Canada	Laval U.	Allard, M.
Canada	Laval U.	Begin, Yves
Canada	Laval U.	Boudreau, Stéphane
Canada	Laval U.	Filion, Luc
Canada	Laval U.	Fortier, Daniel
Canada	Laval U.	Fortier, R.
Canada	Laval U.	Harper, Karen
Canada	Laval U.	Kernaghan, Gavin
Canada	Laval U.	Lavoie, C.
Canada	Laval U.	Lavoie, M.
Canada	Laval U.	Payette, Serge
Canada	Laval U.	Savidge, Rod
Canada	New Brunswick U.	Hermanutz, Luise
Canada	Newfoundland Memorial U.	Green, Scott
Canada	Northern BC U.	Berninger, Frank
Canada	UQ Montréal	Sirois, Luc
Canada	UQ Rimouski	Lévesque, Esther
Canada	UQ Trois-Rivières	Tennberg, Monica
Finland	Arctic Centre, Rovaniemi	Tuulentie, Seija
Finland	Finnish Forest Research Inst.	Eronen, Matti
Finland	Helsinki U.	Hari, Pertti
Finland	Helsinki U.	Gude, Martin
Germany	Jena U.	Vandeberge, Jef
Netherlands	Vrije U. Amsterdam	Myhre, Gunnar
Norway	CICERO, Oslo	Rypdal, Kristin
Norway	CICERO, Oslo	Hofgaard, Annika
Norway	NINA, Trondheim	Skre, Oddvar
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Russia	Centre for Monitoring the Arctic	Vlassova, Tatiana
Russia	RAS	Callaghan, Terry
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Sweden	Abisko Research Stn	Essen, Per-Anders
Sweden	Umeå U.	Moen, Jon
Sweden	Umeå U.	Paschkevich, Albina
Sweden	Umeå U.	Körner, Christian
Switzerland	Basel U.	Rees, Gareth
UK	Cambridge U.	Lloyd, J.
UK	Leeds U.	Crawford, Bob
UK	St Andrews U.	Nelson, Frederick
USA	Delaware U.	Clough, Lisa
USA	East Carolina U.	Griffith, David
USA	East Carolina U.	Johnson, Jeffrey
USA	East Carolina U.	Whiting, Alex
USA	Kotzebue IRA	Lloyd, Andrea
USA	Middlebury College	Cairns, David
USA	Texas A&M U.	Lafon, Charles
USA	Texas A&M U.	Sveinbjörnsson, Bjartmar
USA	UA Anchorage	Macdonald, Glen
USA	UCLA	



History of PPS Arctic

- *IASC project
Tundra-Taiga Interface (TTI) 2000-2005
(www.iasc.no)*
- *IPY EOI: Arctic Border, January 2005
(www.ipy.org #360)*
- *IPY Full proposal: PPS Arctic, September 2005
(www.ipy.org #151)*
- *Ad hoc meeting at ICARP II, Copenhagen Nov 2005*
- *Start-up workshop, Quebec City 16-18 Feb 2006*



Modules

- Global change effects on the arctic-boreal transition zone and modelling structural changes
- Past history and broad scale temporal variations of the transition zone
- *Spatial variations in vegetation, land cover and land use, by remote sensing*
- Land use and development of the tundra-taiga interface through the joint perspective of local traditional and scientific knowledge



Links to other IPY core projects

- *Yehndoo Nanh Nohkhweenjit K'aatr'anahayaa - Environmental Change and Traditional Use of the Old Crow Flats in Northern Canada* (YNNK, #292)
- "Survey of Living Conditions in the Arctic, - Remote Access Analysis System" (SLiCA -RAAS, #190)
- Consortium for Coordination of Monitoring and Observation in the Arctic for Assessment and Research (COMAAR #503)
- **Greening of the Arctic (GOA #139)**
- IASOS-CASEAS
- ITEX (#188)



Spatiotemporal aspects

Objective: To develop effective techniques and carry out quantitative spatial and temporal analysis of the location of transitional ecosystems within the circumpolar tundra-taiga interface.

Task: Determine current location and characteristics of the tundra-taiga interface using remote sensing data, aerial photographs, and geographical information science as well as collecting local and indigenous knowledge.



Circumpolar mapping of present-day ecotone and future changes will make extensive use of Remote Sensing and Geographic Information Systems

We do not fully understand how to do this, but new satellite systems, better access to airborne RS data, new techniques for image processing and pattern recognition, have extended the scope tremendously



Questions to be addressed:

- best source(s) of data - existing data products??
- which algorithm(s) to use
- **scale relations**
- correction for phenology
- changes according to species and along oceanic-continental gradient?



PPS Arctic sites - Western Canada



PPS Arctic sites: Eastern Canada



PPS Arctic sites: Europe

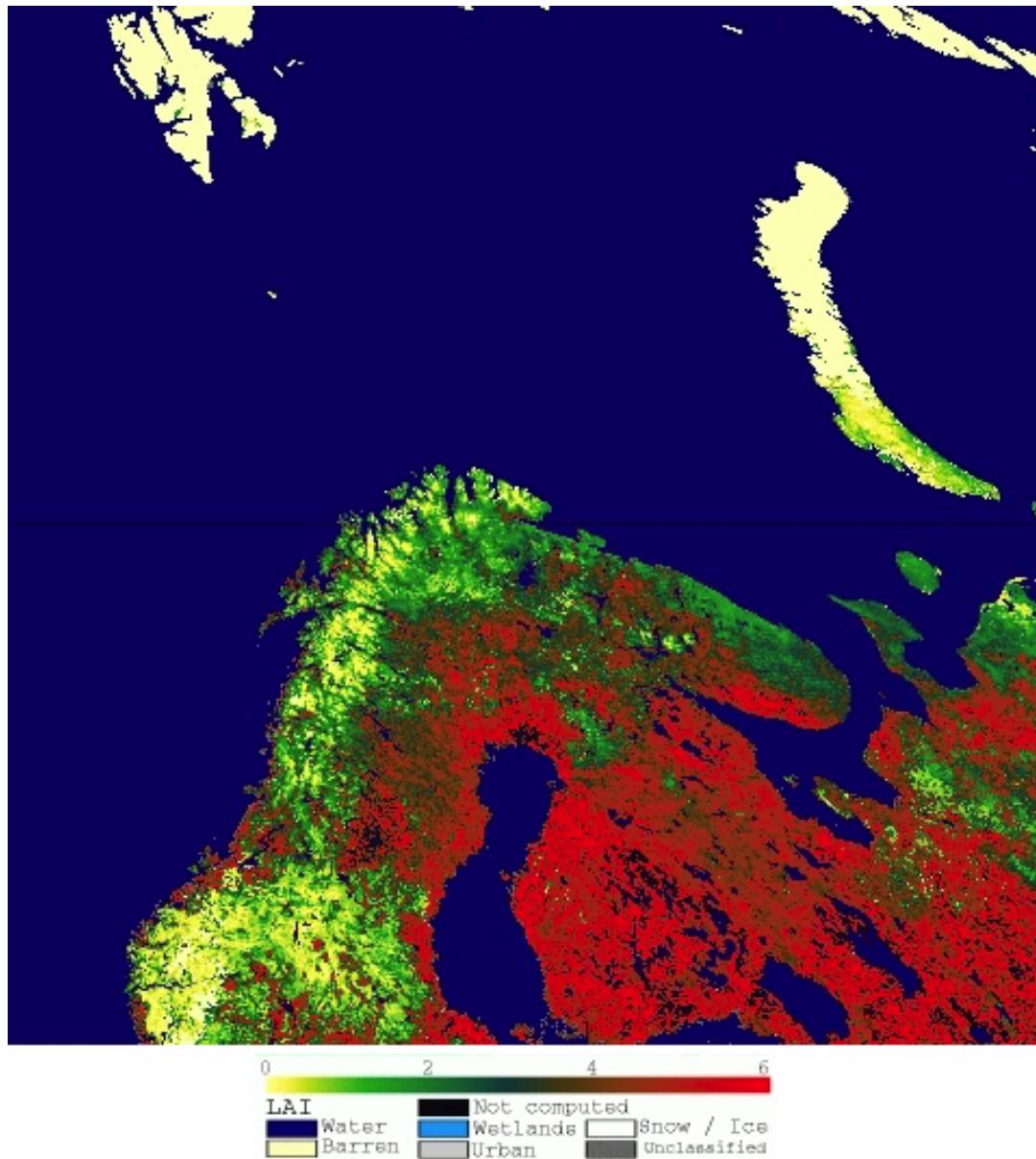


MODIS data products present interesting possibilities but require validation for arctic and investigation of scaling relations

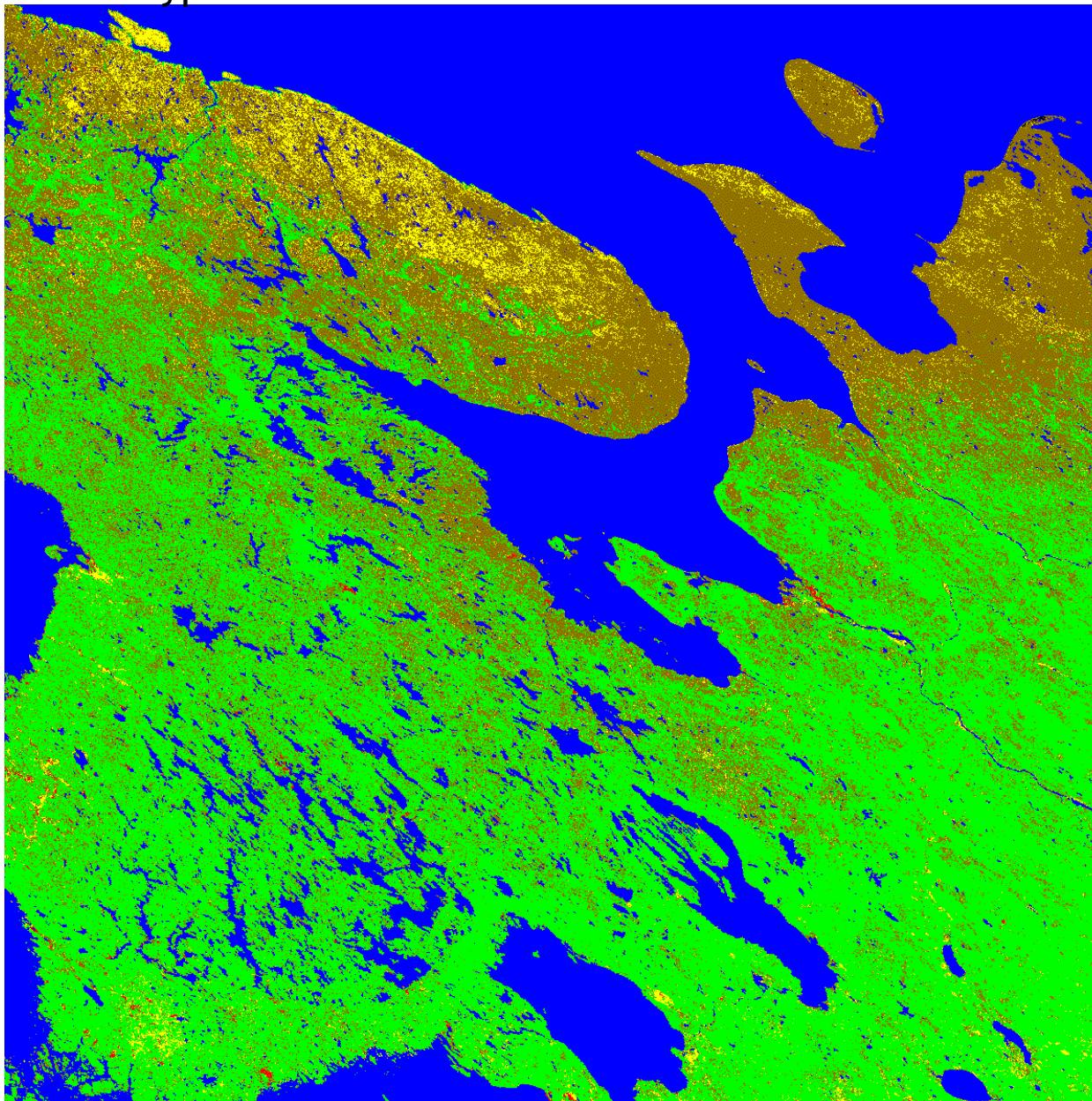
product	parameter	Datasets per product	Temporal resolution (d)	Spatial res. (km)	GB p.a. for arctic
MOD09A1	Surface reflectance	7	8	0.5	51
MOD09Q1	Surface reflectance	7	8	0.25	206
MOD12Q1	Land cover type	3	365	1	0.2
MOD12C1	Land cover type	3	365	5.5	0.004
MOD13A1	Vegetation index	6	16	0.5	22
MOD13A2	Vegetation index	6	16	12	5.5
MOD13Q1	Vegetation index	6	16	0.25	88
MOD13A3	Vegetation index	6	30	1	2.9
MOD15A2	LAI/FPAR	2	8	1	3.7
MOD44B	Vegetation continuous fields	12	365	0.5	1.9



MOD15 Leaf Area Index

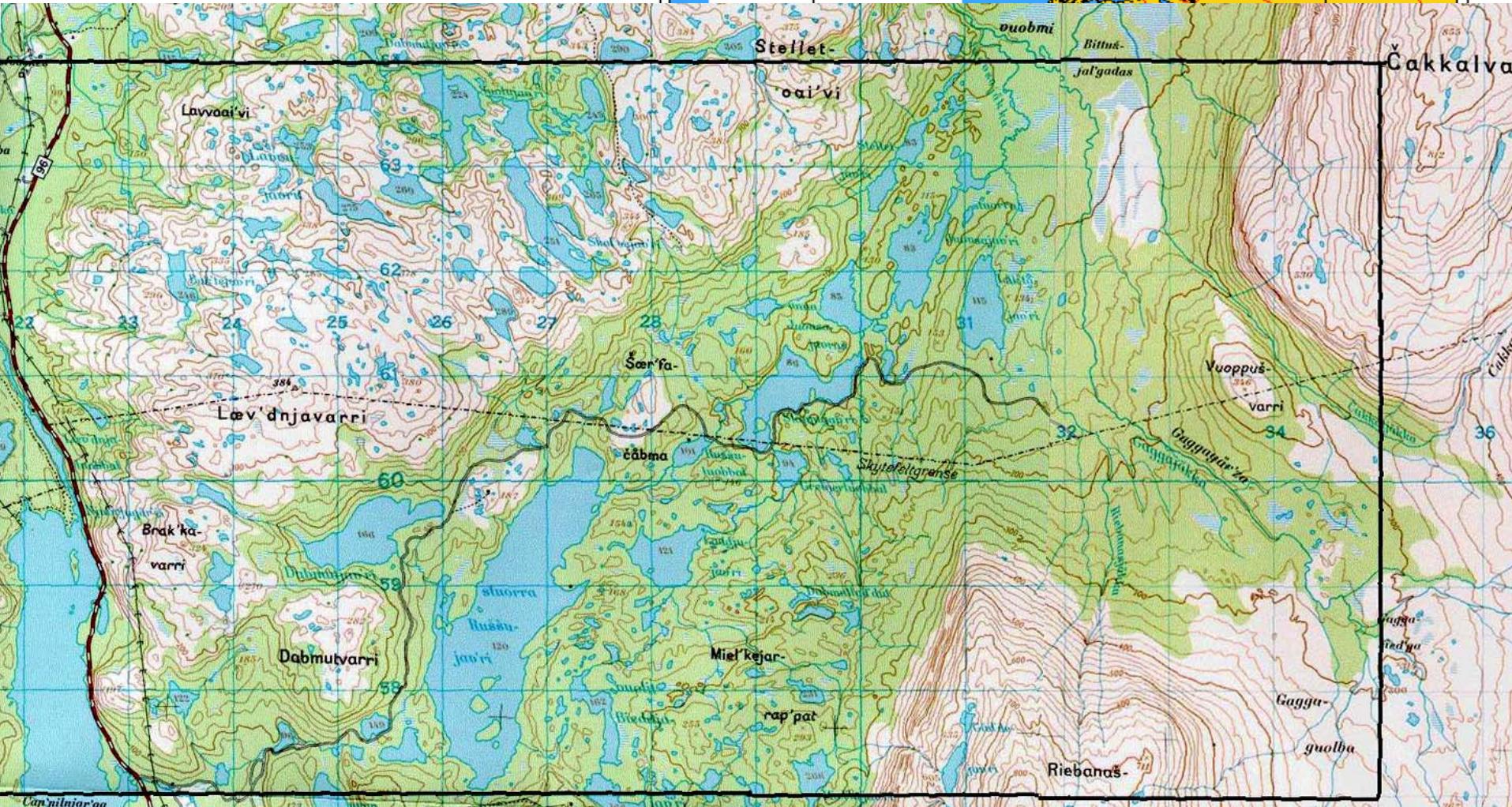
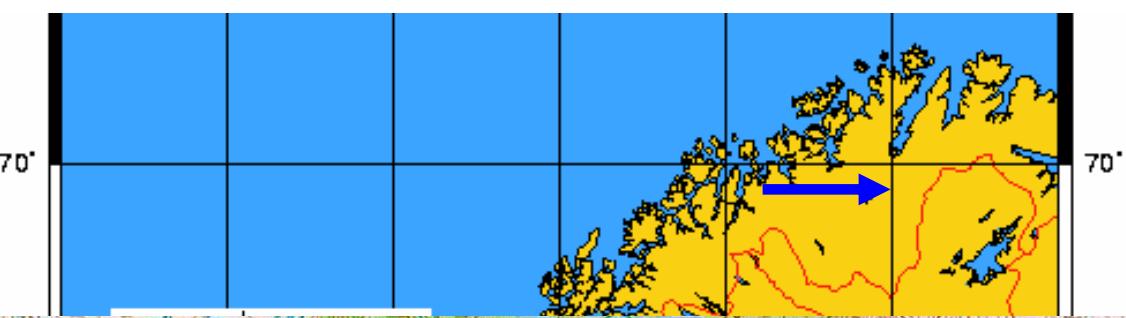


MOD12 Land cover type

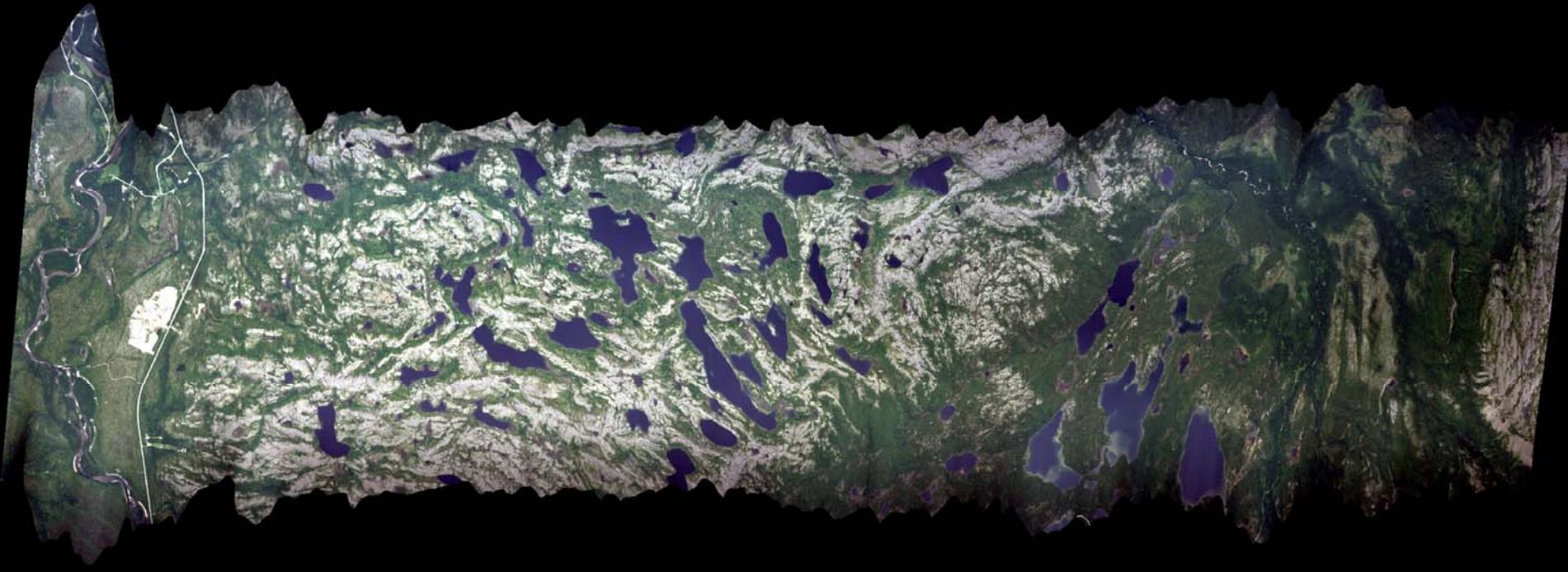


Porsangmoen, Norway

Pinus sylvestris, Betula pubescens



Airborne multispectral imagery (ATM @ 4.5 m, CASI @ 3.6 m) collected during NERC ARSF campaign 20.07.04

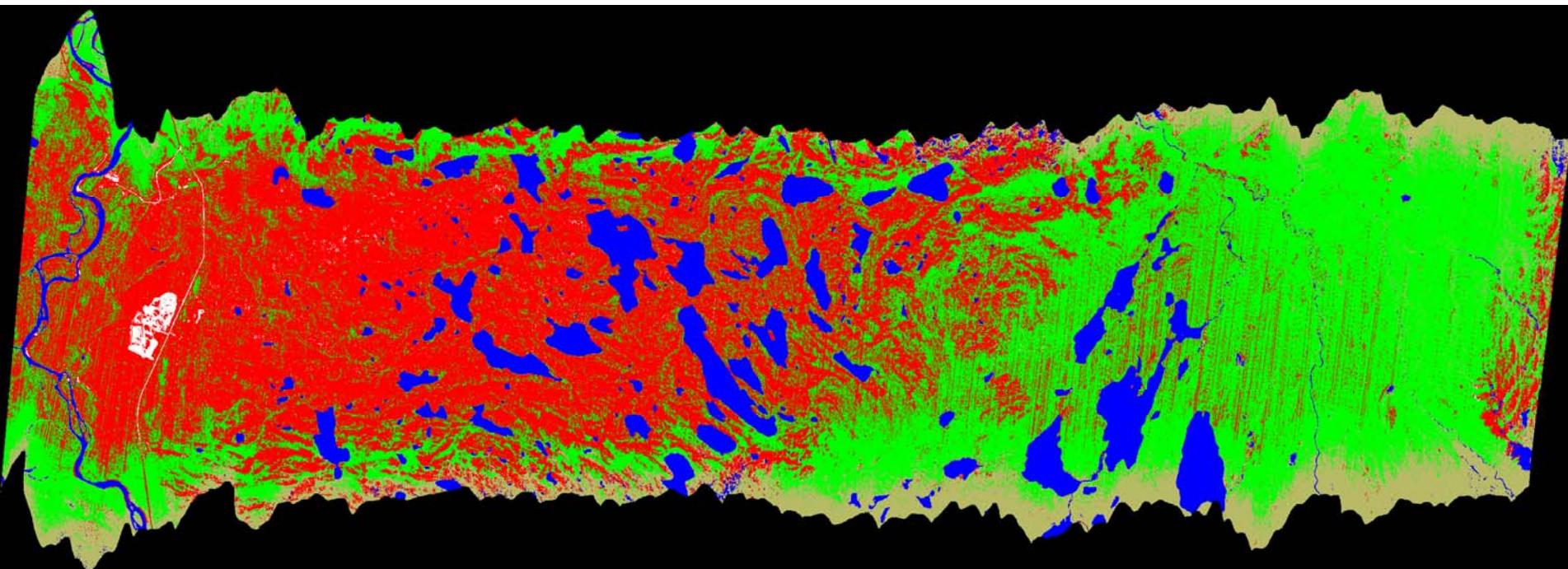


Imagery can be classified, but some problems from
variable imaging/illumination geometry
inadequate georeferencing (difficult to mosaic image strips)
spatial resolution



Simple interpreted ISODATA classification of ATM image strip

- initialised to 30 classes, found 15
- some spectral confusion apparent
- ‘vignetting’ at edges of strip



Optech ALTM3033 LiDAR

- PRF 33 kHz gives sampling of order 1 m from 1000 m agl.
- Scans at typically 30 Hz to give cross-track sampling
- Range accuracy ≈ 0.15 m
- First and last pulse recorded: gives height of target if sufficiently ‘porous’ (works well for trees)
- Viewing geometry determined by dGPS to ~ 0.05 m

Data acquired from Porsangmoen site using ULM LiDAR on NERC ARSF aircraft, 17.07.05.

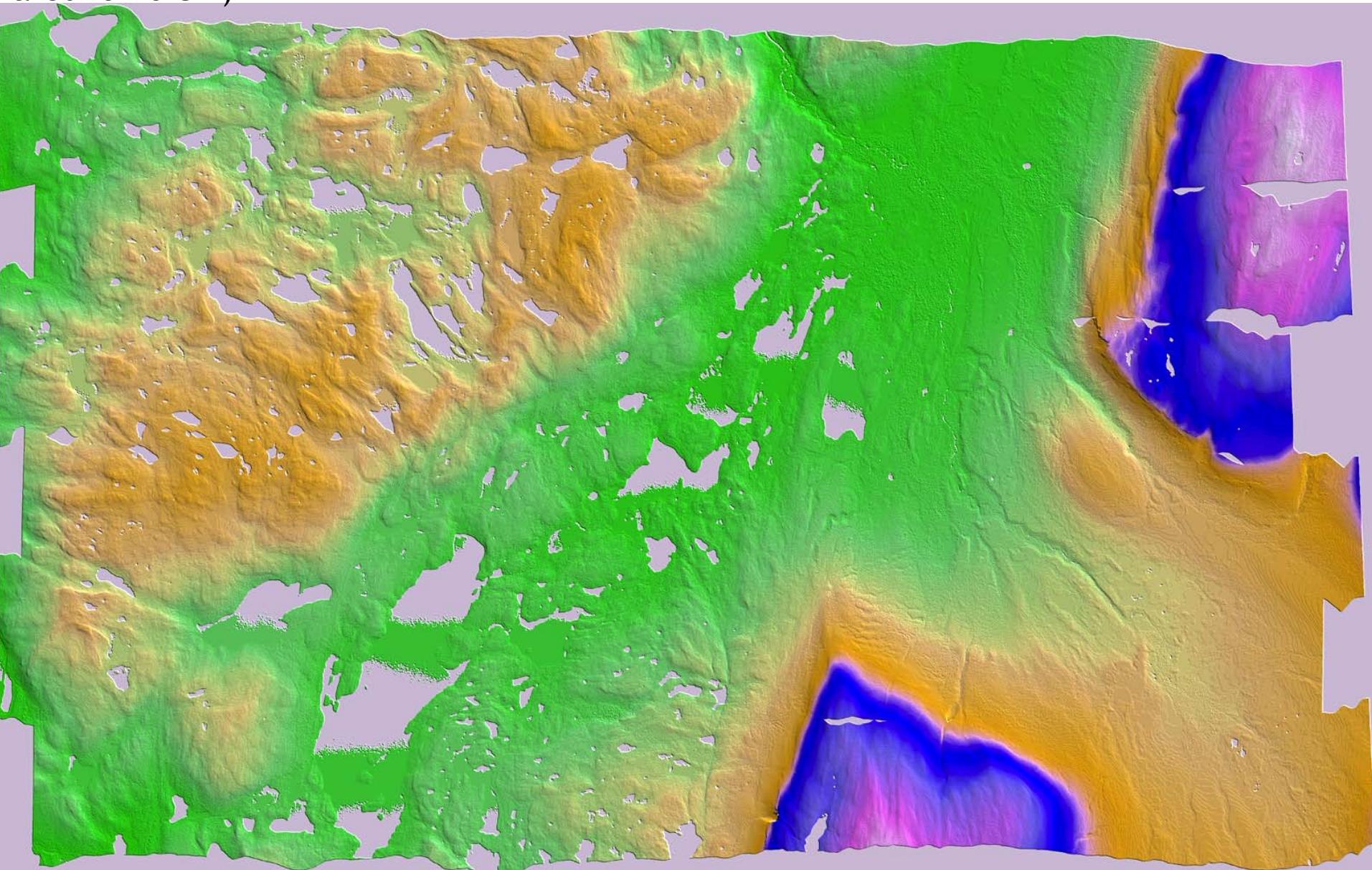
- 33 million points over 126.5 km² (mean spacing 2.0 m)
- 2.3 GB



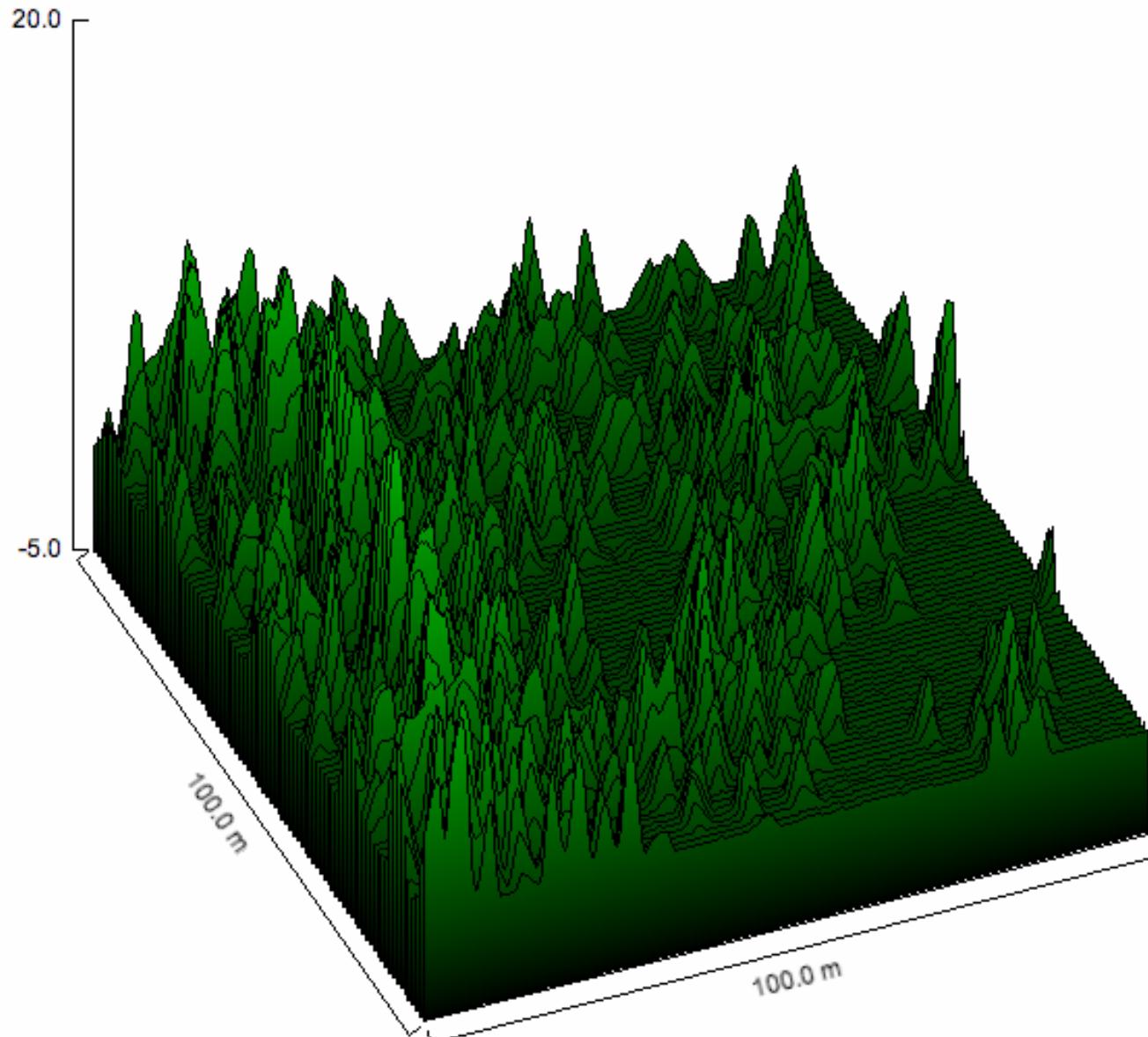
Photo from Naturhistoriska Riksmuseet, Sweden



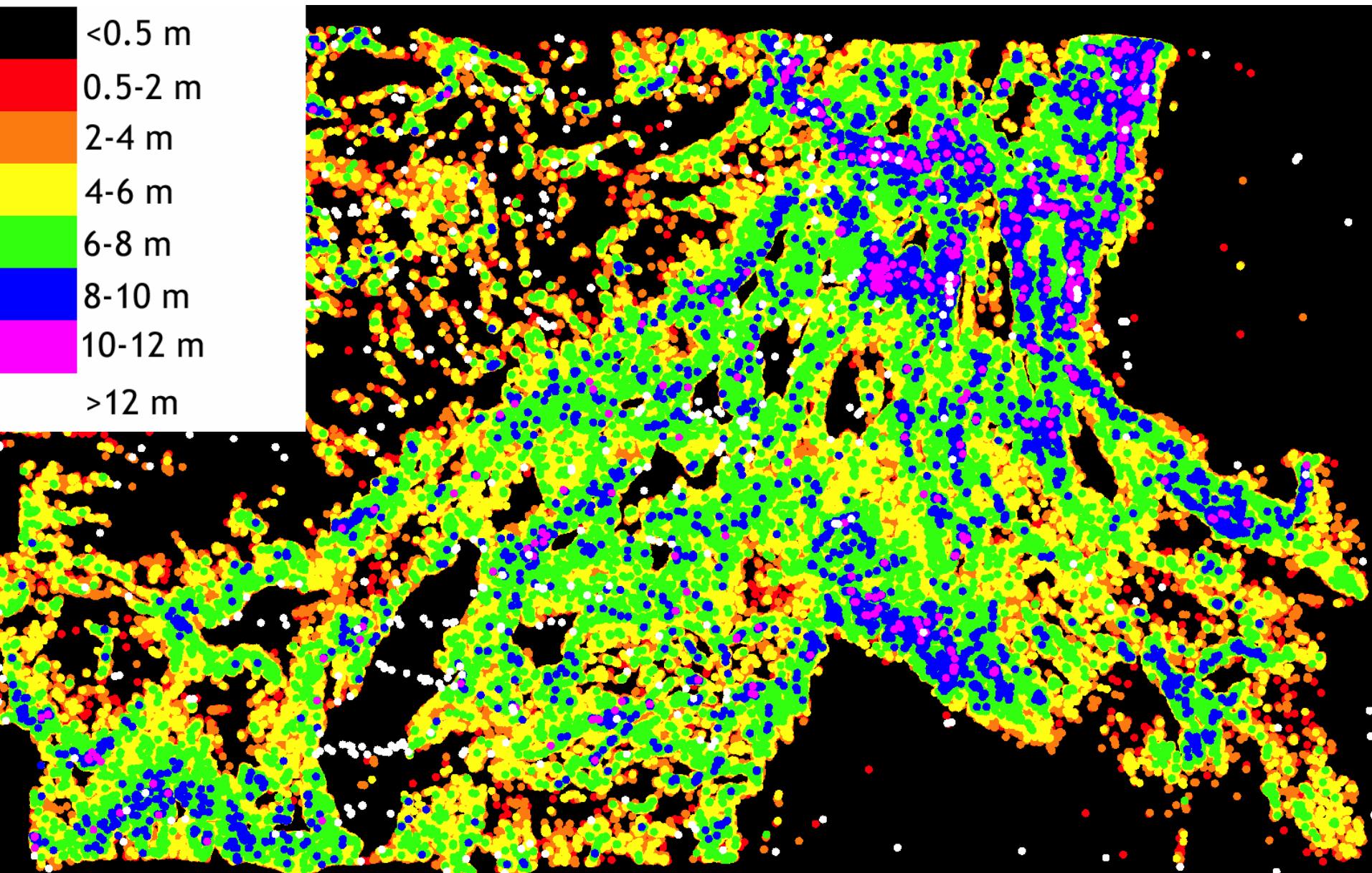
DEM of land surface from last return pulses (gridded to 2 m; vertical resolution around 10 cm)



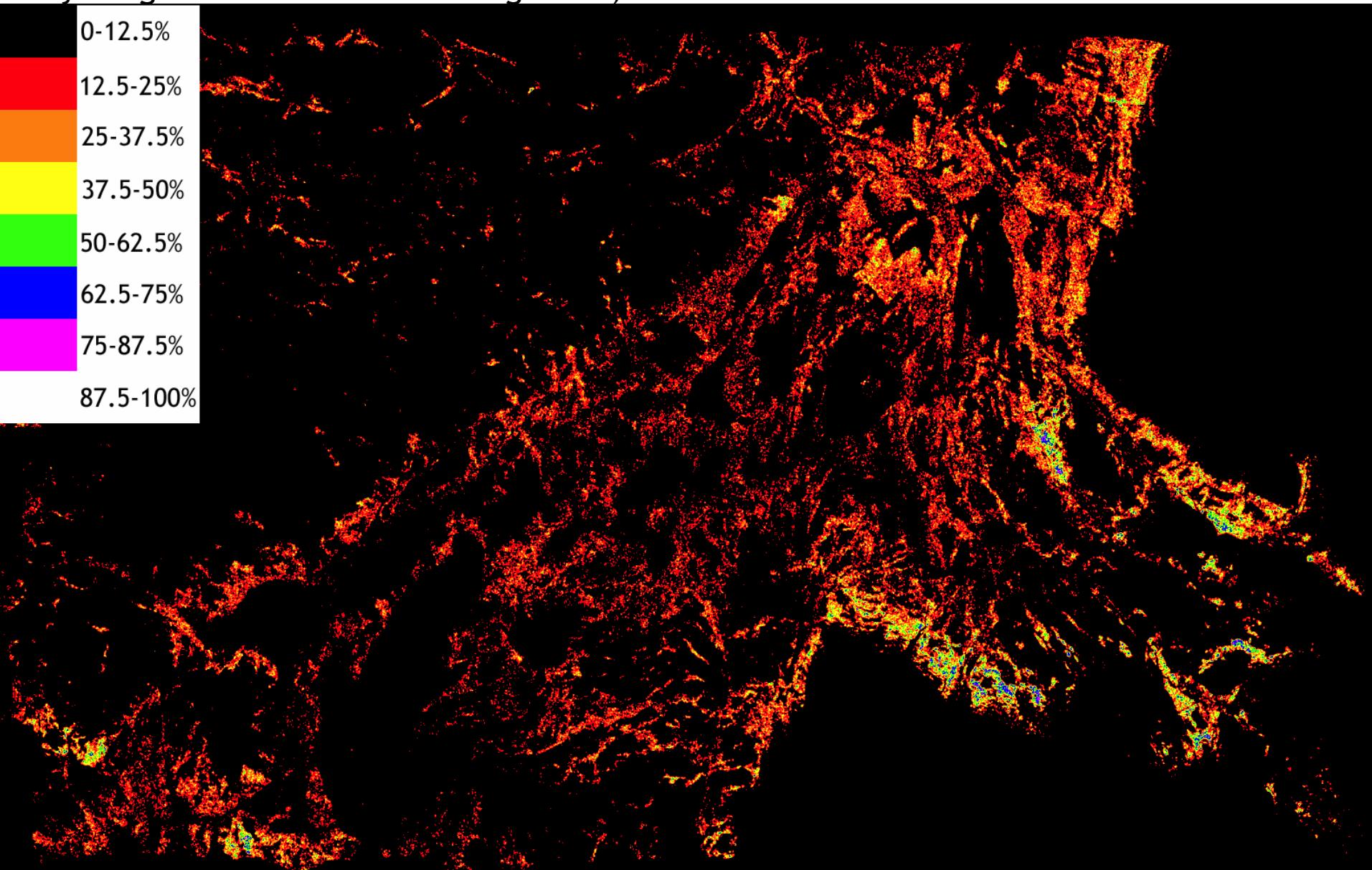
Resolution of pulse difference data allows individual trees to be identified



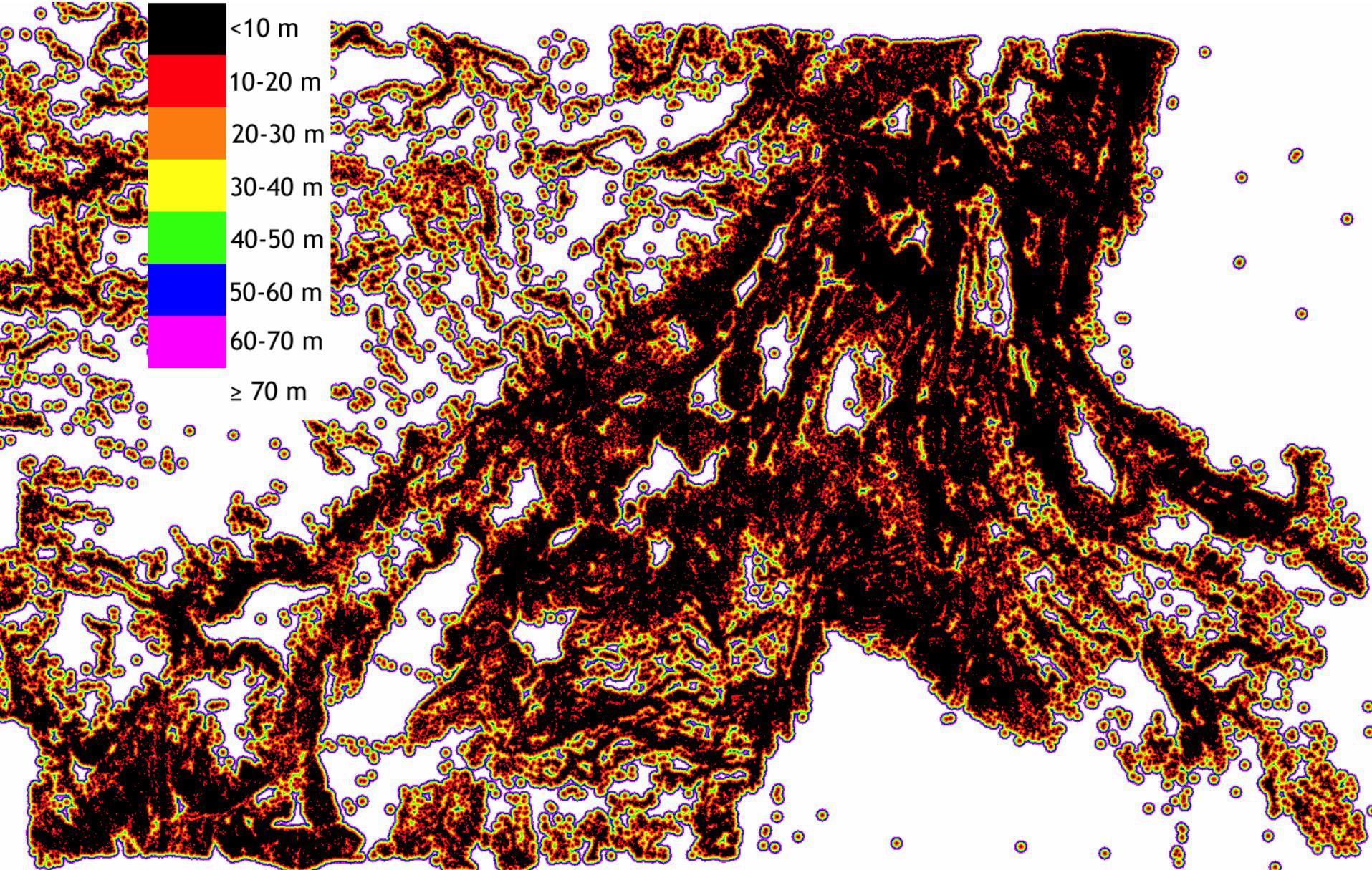
Forest structural parameters - tree height (max. value within radius > tree radius)



Forest structural parameters - canopy density (assume canopy is anything more than 2 m above ground)

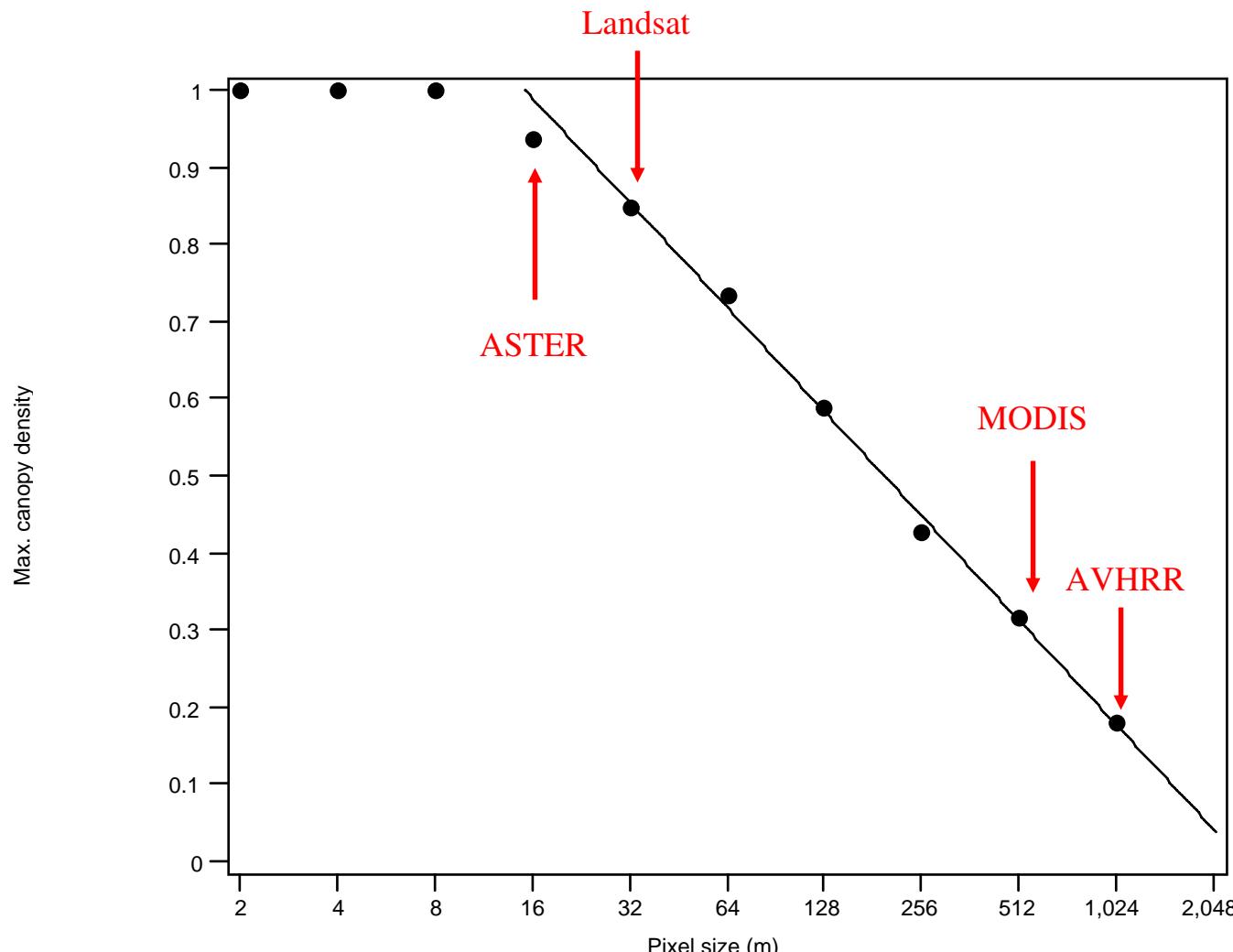


Forest structural parameters - distance to nearest tree (Euclidean Distance Map with 'tree' = anything over 2 m)



Effect of resolution on forest detectability

Choose 8192 x 8192 m region and downscale to from 2 m to 4, 8, 16...
1024 m pixels:



Is the forest a fractal?

Use resolution-dependent threshold to classify downscaled maps

Investigate dependence of forest edge length etc on pixel size p between 8 and 1024 m.

Results:

$$\text{Edge length} \propto p^{-0.93}$$

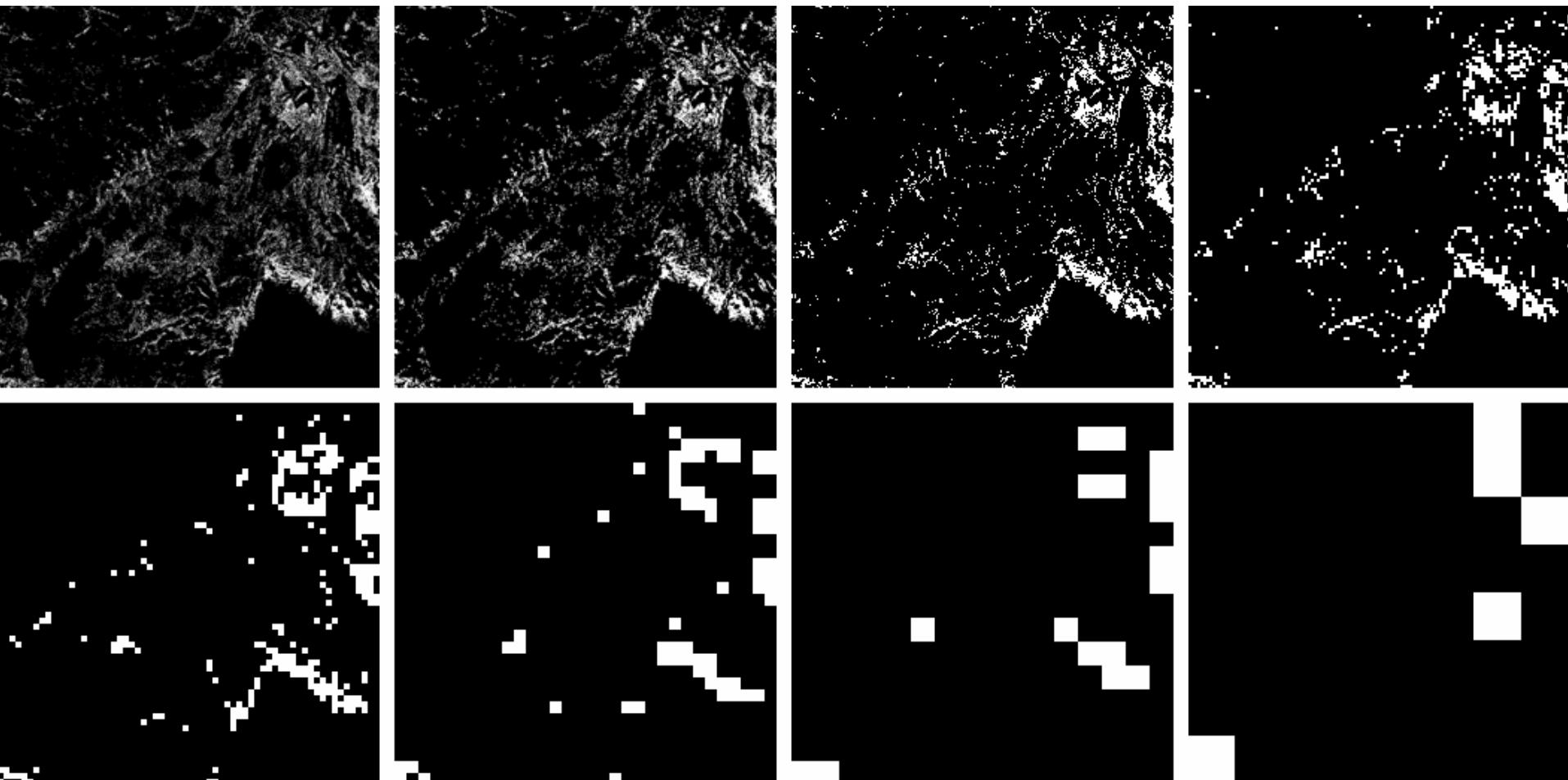
$$\text{Number of discrete regions} \propto p^{1.77}$$

$$\text{Area of largest discrete region} \propto p^{+0.51}$$

Strong evidence of fractal behaviour...



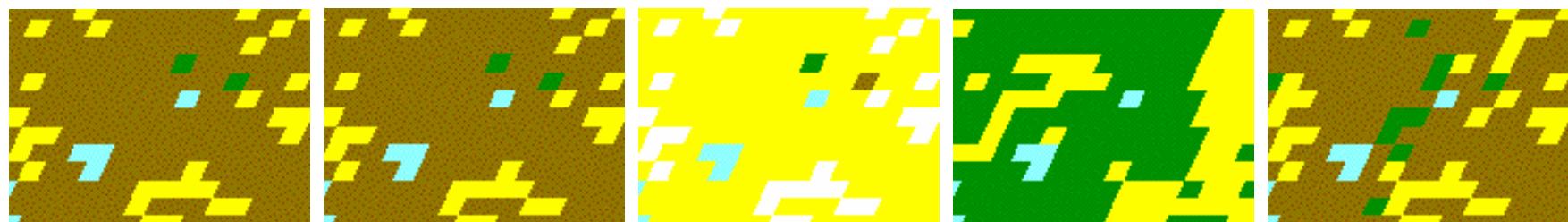
... position of forest edge varies systematically with resolution



What do MODIS products show?

MOD12Q1 - Land cover type (2001)

Yellow: grass & crops; green: forest; brown: shrubland; white: ice and snow; blue: water



Type 1: IGBP global
vegetation
classification
scheme

Type 2: Univ
Maryland
modification of IGBP
scheme

Type 3: LAI/fPAR
scheme

Type 4: NPP scheme

Type 5: PFT scheme



Conclusions *pro tem*

- scaling relations must be established if data having different spatial resolutions are to be combined
and fractal models will probably help
- important to establish common fieldwork protocols for collecting structural data about forest edges
and PPS Arctic is doing this
- MODIS products are not (yet?) optimal for characterisation of treeline
but the resolution is probably not too coarse
- high-resolution LiDAR is a valuable tool for investigation of forest structure at the edges



